Six Elements of Effective Spraying in Orchards and Vineyards

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Factsheet

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INTRODUCTION

The objective of spraying is to deliver an effective, uniform dose of product to a target area in a safe and timely manner. Any product not deposited on the target is called "wastage". Wastage includes drift (vapour and droplet), run-off and any off-target deposition. In high volume airblast applications studies show that 80 per cent of the product can be lost to drift and ground deposition. Wastage not only costs time and money but may reduce the effectiveness of the application and increase the risk of environmental contamination.

There are six elements that affect spray accuracy and wastage to consider before every application. See Figure 1.

Figure 1. Six Elements of Effective Spraying

The elements overlap, illustrating how changes to one element often means reconsidering another. Only the operator affects all elements. Currently no technology or technique can compensate for an inattentive operator; an operator's skill and attitude can greatly improve the accuracy of an application.

Each element is made up of a group of related factors (see Figure 2). This Factsheet provides an overview of how each element affects spraying. Use this information to modify spraying practices to increase accuracy and reduce wastage. It is this balance between benefit and compromise that makes spraying both an art and a science.

EQUIPMENT

Sprayer Design

There are many varieties of directed sprayers commercially available for orchards and vineyards. There seems to be no naming convention between manufacturers and equipment is often customized, so it can be difficult to classify sprayers.

- Conventional airblast uses a single axial fan or turbine. It can be fitted with ducted conveyors in the form of towers, a cannon or a series of flexible pneumatic tubes to direct the spray-laden air.
- Vertical booms can be used with or without an air sleeve, and for compact canopies they can form over-the-row "tunnels" with spray-recovering shrouds.
- Less common in Ontario are the tangential/cross-flow fan-driven towers and the multi-fan systems which are often mounted on flexible vertical booms.

Ministry of Agriculture, Food and Rural Affairs
Ontario

Equipment	Method	Weather	Target	Product	Operator
Sprayer Design **Air - Assist** Orientation Volume Speed **Deflectors** **Spray Quality** Pattern Droplet Size Nozzle Orientation	**Spray Technique** **Forward Speed** Work Rate **Crop-Adapted Spraying** Carrier Volume Dose Rate	**Wind** Speed Direction **Temperature** Relative Humidity	**Canopy Morphology** Time of Season Density-Area **Target** Size Location	**Mode of Action** Timing **Formulation** Density Adjuvants	**Aptitude** **Attitude**

Figure 2. Expanded Elements of Effective Spraying

Any design that maintains a minimal effective distance between each nozzle and their respective target improves deposit uniformity and reduces drift.

For example, consider the distance-to-target at the top nozzles of a conventional airblast sprayer. A lot of product is lost to intervening environmental exposure and spray deceleration, reducing penetration and deposition. The ability to control air speed and redirect flow to match the target canopy is of great benefit when adapting the sprayer to different crops, different zones within a crop (such as the grape zone) or during different stages of growth.

Ducted conveyance (e.g. towers) and vertical booms are growing in popularity as operators pursue better work rates, more accurate deposition, smaller buffer zone requirements and minimal wastage. They are the best choice.

Air-Assist (Orientation, Volume and Speed)

Air assistance carries droplets to the canopy and stirs leaves and branches to aid in penetration. The converging air flows create air turbulence in the canopy and expose all leaf surfaces to the spray. It has been shown that penetration and deposition in full canopies is improved when airflow is angled slightly forward or backward from the direction of travel. If using a tangential/cross-flow system for example, the British Crop Protection Council (BCPC) recommends orientating flow 45° backward and 10° upward. Air can also be used as a deflector, preventing spray-laden air from blowing over the target.

There are differing opinions about the benefits of changing air speed and air volume. Air speed is measured in metres per second and air volume (or airflow rate) is measured in cubic meters per second. In orchards, high volume/low speed air improves overall coverage when the speed is just enough to form openings in the canopy. This does not work under high wind conditions. In vineyards, however, higher air volumes reduce spray-side deposition by blowing spray too far through the target. Some vineyard studies show that using airflow may not be necessary during pre-bloom.

Therefore the appropriate air setting is situation-specific, but in general "more air" does not imply better coverage. Too much airflow tends to carry droplets over or through the canopy, increasing drift potential and reducing coverage. Spray-laden air can actually completely miss a leaf in a process known as slipstreaming. Given the current practice of using too much air, reducing the average fan speed by 25 per cent can potentially eliminate 75 per cent of drift

without compromising coverage. Try to match air speed and air volume to canopy density by:

- using lower power take-off (PTO) speed
- gearing-up and throttling-down
- adjusting blade pitch
- installing a hydraulic motor to control fan speed.

Strategically place water-sensitive cards throughout the canopy, or use kaolin clay (a non-toxic compound that leaves a white, powdery film) to receive feedback for further adjustments. Regardless of air-assist settings, as canopies begin to fill, it is imperative to spray both sides for proper coverage. Even if spray appears in the next alley, it is not providing consistent coverage on the far side of the row being sprayed.

Deflectors

Air deflection research at Cornell University found that fitting adjustable deflectors to the top and bottom of airblast sprayers will direct all exit air into the canopy. The commercially-available deflectors are often too short to effectively redirect air. The variety developed at Cornell is as much as eight times longer and features a metal plate on the front to prevent spray moving forward. Alternately, and preferably, retrofit commercially-available towers to airblast sprayers to redirect air into the target canopy. The Cornell group also developed a low-cost ducted retrofit for Kinkelder vineyard sprayers that reduced wastage and increased deposition by 25 per cent.

Spray Quality (Pattern, Droplet Size and Nozzle Orientation)

Hydraulic nozzles are classified by their spray patterns, flow rates and the range of droplet sizes they produce. This is called "spray quality". More pesticide labels now specify droplet size as well as flow rate. Review this carefully when selecting nozzles.

Note that the droplet size classification system (very fine to extremely coarse) was originally developed for flat fan nozzles spraying into still air under specific conditions. While nozzle manufacturers sometimes provide droplet size classifications for cone-pattern directed-spray nozzles such as disc-core, these ratings do not account for the effects of shear from air-assistance or spraying over larger distances. Tip selection and orientation requires a particularly good understanding of the behaviour of droplet.

Droplet size decreases by increasing:

- pressure
- the nozzle angle into an entraining air stream
- distance-to-target.

With cone-pattern nozzles, often used in directed spraying, a wide-angle spray pattern is subject to more shear and creates finer droplets and vice versa. Droplet size affects droplet behaviour:

- droplets under 150 µm (microns) are particularly prone to drift but offer better coverage
- droplets over 300 µm resist drift but have a tendency to bounce or run upon impact, providing poorer coverage
- droplets in the 100–300 µm range are a good compromise between wastage (drift and ground deposit) and biological effectiveness (target coverage and retention).

The exception is air-induction (AI, or sometimes referred to as Venturi) nozzles, which produce coarser droplets that contain air bubbles. Manufacturers and independent studies show that AI nozzles are a good choice for certain directed applications. The droplets arrive at the target intact and shatter upon impact, increasing coverage while greatly minimizing drift.

Nozzle Orientation

During calibration make sure to aim nozzles at the target. Recent work in Poland with a prototype dual-fan orchard sprayer demonstrated that nozzle orientation plays a larger role in mitigating drift than fan location. This means:

- closing or redirecting nozzles that are off-target
- adjusting angles into the carrier air
- ensuring the desired flow and spray pattern is established.

For fan-driven airblast sprayers, the counter-clockwise turn of the fan carries spray up and over the canopy on the right hand side and downward on the left. Work at Cornell determined that the best spray pattern for the grape zone occurs when nozzles are angled to counteract the "spin": the right-hand nozzles are set to horizontal with the top two set 20° downward and the left-hand nozzles aimed 45° upward. The angles are specific to the sprayer and the intended target. Spin may not be as pronounced on dual-fan and turbine-driven sprayers.

While re-orienting nozzles is very effective, two-fold variations in leaf and fruit spray deposits are typical between the inner and outer portions of vine and orchard canopies, even after spray plumes are optimized for the target. The lesson: spray crops from both sides.

METHOD

The pesticide label is a legal document; do not exceed dose rates. Unless specifically prohibited, lower rates and higher concentrations are allowed. However, there may be consequences, such as reduced protection and increased potential for pest resistance and phytotoxicity. The registrant is only liable if the operator follows the label exactly.

Spray Technique

There are many techniques to apply pesticides in vineyards and orchards, some more effective than others.

- **Cover spraying is recommended**. Cover spraying (or two-way spraying) applies product to each side of every row and ensures proper spray coverage and resistance management. Cover spraying is the only way to achieve effective canopy penetration and uniform coverage during directed applications.

- Do not use alternate row spraying. In this method only one side of each row is sprayed directly. The unsprayed side receives direct coverage on alternate applications. For example, the operator sprays between rows one and two, and returns between rows three and four. On subsequent applications, spraying occurs between rows two and three, etc. Deposition on the far side of the row can be significantly reduced (by up to 50 per cent) compared to the sprayer side. Visual shoulder-checks are not a reliable indication of coverage, even if spray appears in the next row. There are few, if any, exceptions to this recommendation, such as very young plantings and possibly the first few applications where foliage is sparse. In the long term, alternate row spraying is not a reliable method.

- Border spraying is applying pesticide only to the outside edge of an orchard. Sometimes associated with perimeter trap-cropping, this technique tries to create a barrier to invading pests from surrounding wild hosts while keeping beneficial insects and reducing the amount of product required. The efficacy of 20 m-deep border sprays has been shown using organophosphate insecticides in apple and peach orchards, often as part of a protocol that includes an initial conventional cover spray. Do not use border sprays with products other than organophosphate insecticides . If pest injury exceeds spray threshold, return to cover spraying for the remainder of the season.

For all techniques, turn off outward-pointing nozzles at row ends and outer rows.

Forward Speed (Work Rate)

Timing is very important. It relates to pest growth stage, pest pressure, weather conditions and work rate. Given the limited timeframe, it is tempting to speed through an application; but as the canopy fills, it is increasingly important to give spray time to penetrate. As a generality, perform directed spraying between four and six kilometres per hour.

As forward speed increases, spray can be diverted backwards into upward wind currents and vortices behind the sprayer. This increases variability in spray deposit, which is generally undesirable and it adds to drift. This effect is amplified when driving into the wind because the shearing effect increases the number of driftable fines, even when using coarser droplets. One study on boom spraying showed that reducing speed from eight to six kilometres per hour has the potential to reduce drift by ~50 per cent.

When performing airblast applications, canopy penetration and uniformity is greatly improved at slower speeds. Air and droplet velocity has a high rate of drop off, and this loss of momentum means it takes time for spray to get to the target. Work in apple orchards demonstrated that high volume/low speed air used at low forward speed results in a large increase of air volume penetrating trees

Studies in grapes demonstrated that increasing air volume does not compensate for higher forward speeds; it reduced deposition on the spray side of a fully developed canopy, while it did not affect deposition on the far side. Moreover, the backward angles increased variability and ground deposition beneath vine rows. Adding more carrier liquid will not permit a higher forward speed, either. This will only increase the material deposited on the area already sprayed.

Ways to save time without increasing forward speed include:

- investing in an additional sprayer
- investing in faster filling systems
- employing over-the-row sprayers to apply to multiple rows in a single pass
- using moderately lower carrier-volumes or refill vehicles
- reduce row spacing and adjust hedging/ pruning practices.

Carrier Volumes

The purpose of the carrier (usually water) is to convey product to the target and distribute it in the desired pattern and concentration. The volume of liquid to use during directed spraying is seldom indicated on a label except in general terms (i.e. maximum and minimum). Therefore, carrier volume is often determined by the equipment used, crop morphology, pest location, the mode of action and personal considerations including past performance, work-rate and environmental impact.

The volume of liquid retained on a surface is limited, so once wetted the surplus drips down to the lower leaves and so on to the soil. Once run-off begins, the amount of product deposited is proportional to concentration but independent of carrier volume. Properly calibrated, the same amount of product will be deposited on all portions of the target without incurring run-off.

High Volume Spraying

High volume spraying (>2,000 L/ha in a high-density orchard, 500–1,000 L/ha in vineyard) uses a wide range of droplet sizes and is the simplest and arguably more dependable form of spraying. The objective is to thoroughly wet all portions of the branches, blossoms, fruit and leaves just to the point where excess spray begins to run off. This can be difficult to achieve given that outer leaves reach the point of run off before inner leaves are suitably covered. Pruning, training and hedging combined with a slower forward speed can help by allowing spray materials to travel throughout the canopy.

Although at first glance the simplest technique, spraying large volumes:

- incurs wastage via soil contamination
- contributes to soil compaction
- makes timely spraying difficult due to the extra refills.

Low Volume Spraying

Low volume spraying employs less liquid than needed to thoroughly wet the target. While benefits include reduced soil contamination and fewer refills, it requires very accurate spraying to compensate for the lower volume. Coverage can be improved by using smaller droplets in greater numbers, but this incurs an increased potential for drift. In addition, the dose rate for most agricultural chemicals is determined through high volume spraying, so the concentration of the product is often increased proportionally as the carrier volume decreases. Higher concentrations are intended to maintain effective dosage, but this increases the risk of phytotoxicity.

Dose Rate

Historically, dose rates for orchard spraying in Ontario were determined through efficacy trials where standard trees (4.5–5.5 metres high) were sprayed to runoff with a handgun at 3,740 L/ha (400 US gal/ac), and the effective rate was expressed per 378.5 L (100 US gal.). Label rates are still determined through trial and error, but are tested using today's denser, size-controlled plantings.

These modern crop protection products often express dose rate as the lowest effective amount of product applied per hectare of crop. While area-based rates are ideal for boom or aerial spraying over workable crops, orchards and vineyards are three-dimensional targets planted in rows and are typically sprayed from within the canopy. Depending how efficacy was originally determined, it is possible to over-apply for small plants with large spacing in early season, or to under-apply for large plants in dense plantings late in the season.

When direct spraying do not rely solely on product per hectare. Instead, adjust spray volume to match the density and volume of the target canopy by:

- shutting off nozzles
- changing nozzles to different rates
- adjusting travel speeds
- rely upon personal experience in past seasons.

Crop-Adapted Spraying (CAS)

Crop-Adapted Spraying matches the carrier volume and/or dosage to the size, shape and density of the target crop.

Many models have been developed to guide operators in their decision to modify application rates, each relying on certain assumptions with varying degrees of success.

For orchards, the most popular CAS models include the relatively new Pesticide dose Adjustment to the Crop Environment (PACE+) and the more established Tree-Row Volume (TRV).

PACE+

The PACE+ system relies on a pictographic key and a simple formula for growers to calculate dose adjustments for certain pesticides. However, it assumes sprayer efficiency, has no link to growth stage, does not perform well in highly variable orchards and has only been demonstrated on a few varieties in the UK.

TRV

The TRV system translates ground-area rates to volumetric rates using a formula based on tree height, width, row length and distance between rows. It does not account for sprayer efficiency or the area-density of the canopy, which accounts for 80 per cent of the deposit variability between canopies. Therefore, TRV is generally considered too complex and is only a partial solution.

UCR

For vineyards, the Australian Vine Row Volume (VRV) was replaced by the Unit Canopy Row (UCR) concept which also adjusts the application rate requirements on the basis of crop row-length rather than ground-area. However, UCR does not consider the canopy type, area-density or sprayer efficiency.

Ontario options

Many of these models are complicated, and have proven inaccurate or inappropriate for Ontario growers. As a result, growers have adopted their own methods using a trial and error approach, which may or may not provide adequate coverage.

Until a simple and consistently effective CAS system is developed, only mechanical changes to nozzle orientation, airflow and droplet size are recommended.

WEATHER

Wind (Speed, Direction)

- Only spray when wind direction is consistent and between 2–15 km/h, or as indicated on the product label; measure wind outside of the orchard/vineyard on the upwind side.

- Too little wind can leave finer droplets suspended in the air, prone to evaporation and potential drift to unintended targets long after spraying is completed.

- High speed or changeable (i.e. gusty) winds will carry droplets through or over plantings.

- Depending on the fullness of the canopy, wind speed is higher at the border zones, like the outer rows and the tops of the canopy. Therefore, spray with a crosswind towards unsprayed areas and only apply sprays when the wind direction is away from sensitive areas (e.g. non-target areas).

- Be aware of sensitive downwind areas such as open water and areas of human activity. Set up buffer zones as indicated on the label.

Temperature (Relative Humidity)

- Spray when temperatures are low and relative humidity is high. This reduces the chance of drift due to temperature inversions or evaporation and increases the chance of deposition on the target.

- Conditions are often optimal in the early mornings following overcast nights, but spray in the evening/night if there is a possibility of disrupting bee activity.

- In general, do not spray when relative humidity is less than 40 per cent and/or temperatures exceed 25°C.

- When planning to spray, consider local forecasts and consult the label for product application specifications such as drying time, absorption and retention.

- If conditions become too adverse stop spraying until they improve.

TARGET

Canopy Morphology (Stage of Growth)

- Recalibrate sprayers as the season progresses, not only to confirm good working order, but to reorient nozzles and air assistance to match canopy changes as they grow and fill.

- More growers are using automated canopy sensing systems that reduce wastage by closing individual nozzles when there are gaps in the canopy. Traditional practice in airblast orchard spraying is to close nozzles that spray over or under the canopy and to choose nozzles with progressively smaller outputs further from the centre position of the boom. This is still sound advice, providing the top of the tree receives sufficient coverage.

- Use similar logic in vine spraying, but depending on the reason for the application, concentrate on the fruiting zones as the season progresses.

Dense Foliage

As noted previously, increasing foliar density requires pruning, training and hedging, changes to air assist settings and slower forward speeds to ensure adequate penetration and uniform coverage.

- Monitor deposition when changing any spraying parameters.

- Place water-sensitive cards at the top, middle and lower potions of the canopy both on the spray-side surface and deep within the canopy.

- Alternately, use kaolin clay and note the deposition pattern.

Target (Size and Location)

The goal of spraying is to deliver an effective, uniform dose of product to the target area. Depending on the nature of the pest, the target area may or may not include all portions of the canopy.

Tips to help reach the target:

- adjust the spray angle or increase turbulence within a canopy for improved under-leaf deposition
- increase water volume to the point of run off to penetrate canopies and help spray run into crevices in bark
- combine smaller droplet size and slower forward speed to improve retention and increase droplet density on all surfaces, such as under leaves or around fruit.

PRODUCT

Mode of Action (Timing)

It is important to understand when and how to apply any pesticide or growth regulator. Timing considerations include:

- compatibility with work schedule and harvest dates
  - the label specifies re-entry and harvest intervals as well as rainfast period
- target pest susceptibility
- understanding how the product works or its mode of action
  - the mode of action may require that a product be deposited in a specific location, or with a minimally effective droplet density

It has been suggested that droplet number per square centimetre is more important than droplet size for determining pesticide efficacy. A product can work by immediate physical contact with a pest or in a secondary manner, such as a systemic product.

For example, a product may require an insect to move through the deposit when dry, or impact the pest at a susceptible stage of development during application. Alternately, the product may be taken up by the plant, or require the pest to ingest it.

It is for this reason that labels increasingly specify droplet size. But if this information is not provided, use finer droplets for contact insecticides and fungicides, and coarser for systemics. There will always be exceptions, such as using localized treatments or discrete droplets to allow greater survival of natural enemies. Never use directed applications (e.g. airblast) to apply herbicides.

Formulation (Density and Adjuvants)

Nozzle rates in catalogues are based on spraying water, which weighs 1 kg/L. When spraying solutions are heavier or lighter, use a conversion factor (found in nozzle catalogues) to determine the correct nozzle size.

Density conversion formula

Desired application rate (L/ha) ×
Conversion Factor based on weight
= Actual application rate (L/ha).

In some cases, the difference may be enough to require the next lowest or next highest flow rate. Depending on the volatility of the product, consider shorter distances to target and larger droplets to counteract evaporation.

Adjuvants

Adjuvants are sometimes added to a tank mix, separate from the pesticide formulation, to improve performance. There is a wide variety of registered adjuvants; caution is advised. Some pesticide formulations are not compatible with certain adjuvants and the label specifies what to use.

- Wetter-spreaders cause more contact between a droplet and a surface (usually used for waxy or hairy leaves), but too much can increase run-off.

- Stickers adhere droplets to a target, reduce evaporation and increase rain-fastness, but they also increase the viscosity of the spray and change spray quality.

- Drift retardants reduce the number of driftable fines, but droplets are larger and there are fewer of them, which lowers droplet density on the target.

- Emulsifiable oil activators enhance the penetration of certain products through the waxy surface of the leaf but this is plant and product specific and cannot be applied ad hoc.

- Still others include buffers, compatibility agents foam retardants and other minor purpose adjuvants.

OPERATOR

Aptitude and Attitude

Many effective application technologies and pest control products are available — but they must be used correctly. Effective application begins with observing the Integrated Pest Management (IPM) process:

- diagnose the problem
- monitor the problem
- control the problem, and
- monitor the results.

The first two steps mean identifying the pest, understanding the nature of the pest (such as the life cycle) determining a threshold of tolerance. If spraying is required to control the problem, the operator needs to know the basics of spray technology. This includes the equipment and the effects of changing spraying parameters (such as pressure or carrier volume), the impact of weather conditions (such as wind and relative humidity) and the product being applied (such as correct timing and safety requirements). Knowing how to properly maintain, calibrate and orient the sprayer according to the nature of the target is also important.

Finally, monitoring the results requires responding to changes in the environment and target during application and to consider these factors when evaluating the outcome.

CONCLUSION

Ultimately, the effectiveness of an application is determined by the operator's understanding of the elements that influence spray application and the decisions they make when balancing benefit and compromise.

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REFERENCES

R.M. Trimble. *Modified summer programme using border sprays for managing the codling moth, Cydia pomonella (L.) and the apple maggot, Rhagoletis pomonella (Walsh) in Ontario apple orchards.* 1995. Agriculture and Agri-Food Canada published abstract.

H. Erdal Ozkan. *Effect of major variables of drift distances of spray droplets.* AEX-525-98. 1998. Ohio State University.

P. Goodwin. *Guide for spraying fruit trees.* Agdex#210/606. 2000. Ontario Ministry of Agriculture, Food and Rural Affairs.

G.A. Matthews. *Pesticide application methods.* 3rd Edition. Blackwell Science Ltd. 2000.

J.M. Witt. *Agricultural spray adjuvants.* c.2000. Oregon State University.

A. Landers. *Machinery selection – Crop sprayers for orchards and vineyards.* 2000. Cornell University.

S.A.Bound. *Spray technology in perennial tree crops.* In: Production practices and quality assessment of food crops. Vol 1. Preharvest Practice. 2004. R. Dris and S.M. Jain (Eds.). pp83-104.

A. Landers and M. Farooq. *Factors influencing air and pesticide penetration into grapevine canopies.* Aspects of Applied Biology. 71, 2004. pp.343-348.

B. Panneton, B. Lacasse and R. Thériault. *Penetration of spray in apple trees as a function of airspeed, airflow, and power for tower sprayers.* Canadian Biosystems Engineering, Volume 47, 2005. pp.2.13-2.20.

D.W. Manktelow and S.J. Gurnsey. *Deposit variability and prediction in fruit crops: What use are label rates anyway?* Aspects of Applied Biology. 71, 2004. pp.269-278

B. Panneton, B. Lacasse and M. Piché. *Effect of Air-jet configuration on spray coverage in vineyards.* Biosystems Engineering. 90 (2). 2004. pp.173-184.

Cooperative Research Centre for Viticulture. Viti-Notes: Effective chemical use 4. Understanding chemical 'modes of action'. 2005.

D. Nuyttens, M De Schampheleire, W. Steurbaut, K. Baetens, P. Verboven, B. Nicola, H. Ramon and B. Sonck. *Experimental study of factors influencing the risk of drift from field sprayers, Part 1: Meteorological conditions.* Aspects of Applied Biology. 77, 2006. pp.321-329.

P. Jaeken, C. Debaer, A. De Moor, and P. Creemers. *Influence of orchard phrenology on surrounding wind speed levels within the orchard.* Aspects of Applied Biology. 77, 2006. pp.505-512.

British Crop Protection Council. *Your guide to using pesticides.* 2007.

A. Godyn, R. Holownicki, G. Doruchowski, and W. Swiechowski. *Dual-fan orchard sprayer with reversed air-stream – Preliminary trials.* Agricultural Engineering International: the CIGR Ejournal. Manuscript ALNARP 08 007. Vol. X. May 2008.

J.V. Cross, and P.J. Walklate. *The UK PACE scheme for adjusting the dose to suit apple crops.* Agricultural Engineering International: the CIGR EJournal. Manuscript ALNARP 08 003. Vol. X. May, 2008.

S.J. McArtney, and J.D. Obermiller. *Comparative performance of air-induction and conventional nozzles on an axial fan sprayer in medium density apple orchards.* HortTechnology. 18(3), 2008. pp.365-371.

A. Landers. *Improving sprayer efficiency.* 2009. Cornell University.

T. Wolf. *Pesticide application and choosing the right nozzles – FAQ.* 2009. Saskatchewan Ministry of Agriculture Factsheet.

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